City of Norfolk
City-wide Coastal Flooding Study
Presentation to
Storm Water Working Group

February 29, 2012

Kevin Smith
Associate Engineering Geologist
Fugro Atlantic

Introduction and Purpose

- During previous meeting (November 29, 2011) citizens requested more information regarding coastal flooding study
- Presentation provides overview of study
- City-wide coastal flooding study initiated in 2007
  - Part of City's ongoing efforts to proactively address flooding
- Project team comprised of:
  - Civil, coastal, and geotechnical engineers
  - Geologists, oceanographers, and GIS analysts
  - Moffatt & Nichol and Timmons Group

Why Flooding Occurs

In Norfolk, flooding is caused by rainfall, tides or a combination of both

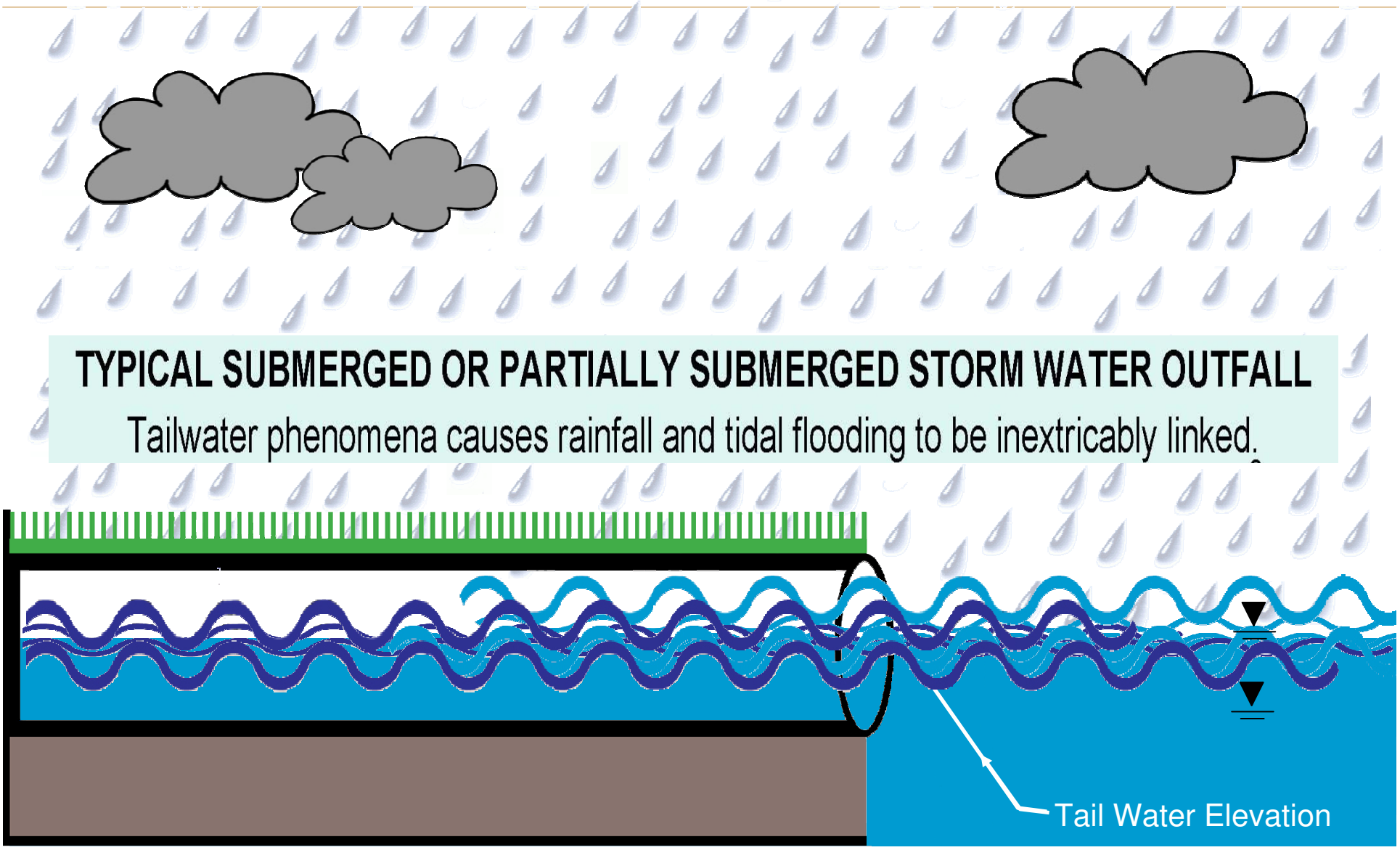
Precipitation (Rainfall) Flooding

- Rain intensity exceeds capacity of the storm drain system

Tidal (Coastal) Flooding

- Caused by tidal variations and storm surges
- Directly related to land elevation and proximity to coastline
- Can exacerbate rainfall flooding

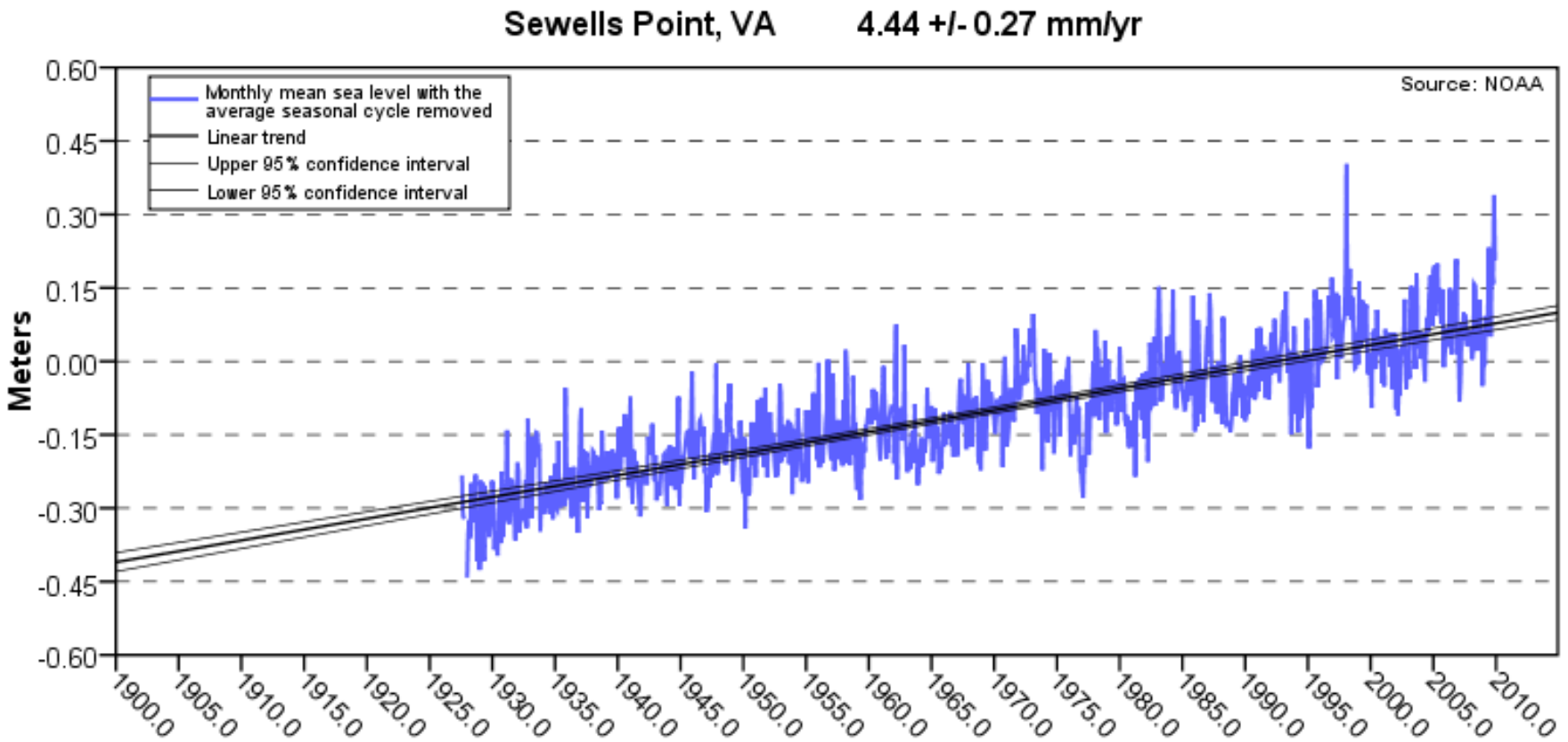
Rainfall and Tidal Flooding



Relative Sea Level Rise

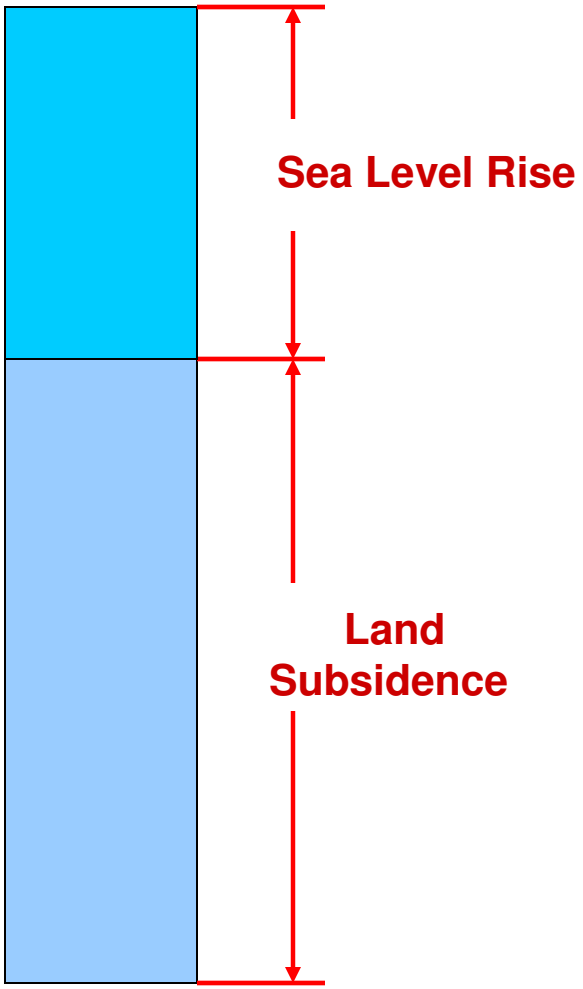
Since 1930, relative mean sea level at Sewells Point has been documented to have risen 14.5 inches

• Rate of sea level rise has been increasing over time and is projected to continue increasing



(NOAA, Tides and Currents, Sea Level Trends, 2010)

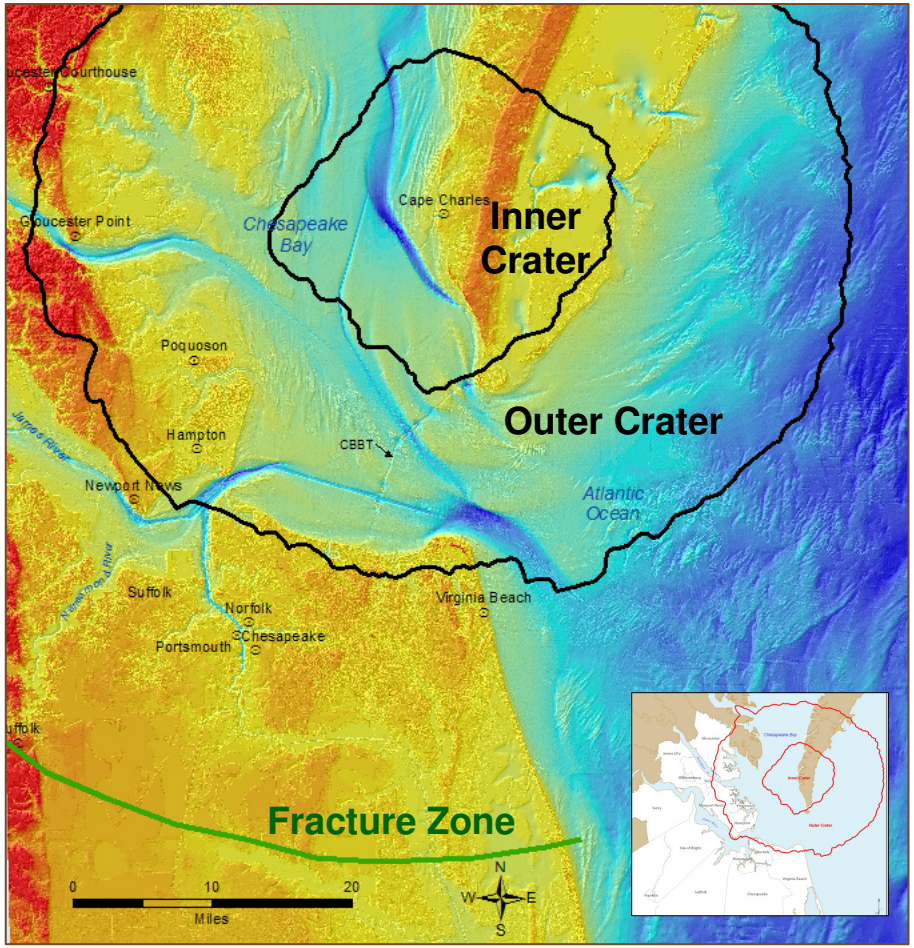
Relative Sea Level Rise



- Relative Sea Level = Global Sea Level Rise + Land Subsidence
- Among Scientists there is a wide range of future sea level rise projections
- Mid-range future projections of Relative Sea Level Rise for Hampton Roads are 2 - 4 inches per decade

Land Subsidence

- Land subsidence is occurring faster in Hampton Roads than surrounding areas
- Subsidence causes
  - Chesapeake Bay Impact Crater
  - Groundwater withdrawal
  - Glacial rebound
  - Compaction of sediments
  - Reclaimed land
  - Other issues

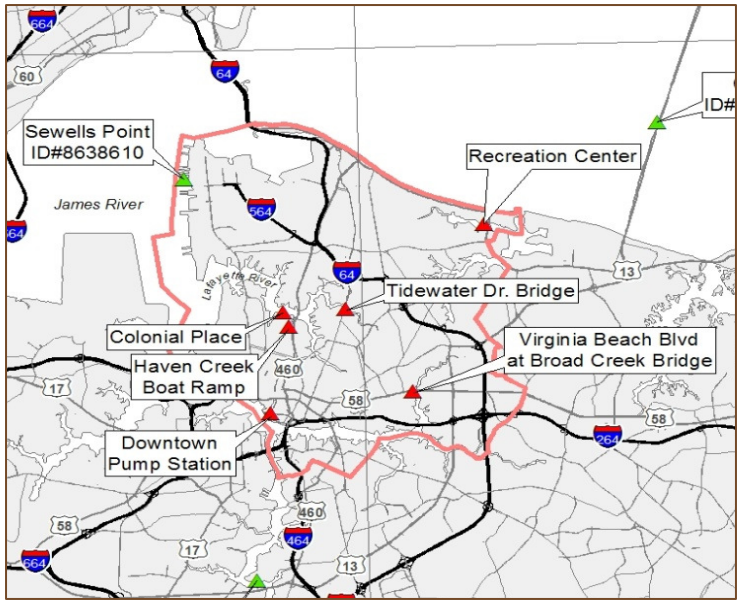


Chesapeake Bay Impact Crater and Elevation Model

Impact Crater from Powers and Bruce (1999); DEM (NOAA, 2004); Inset map HRPDC

City-wide Coastal Flooding Study

- Comprehensive study
  - Installed tide gauges throughout city
  - Completed a City-wide assessment and began focused watershed evaluations to determine range of options that may be needed for effective flood relief



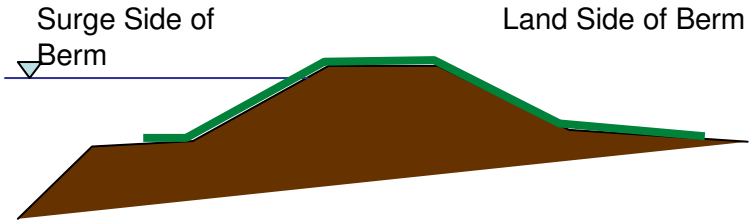
Mitigation Options Considered

- Public Information, Notification and Education
- Land use options & Government policy
  - Zoning regulations
- Development requirements
  - Minimum floor elevations for house
  - Minimum floor elevation for garages and ancillary structures
  - Flood proofing vulnerable elevations
  - Foundation, structural, mechanical design requirements
- Property Purchase
- Infrastructure Approaches

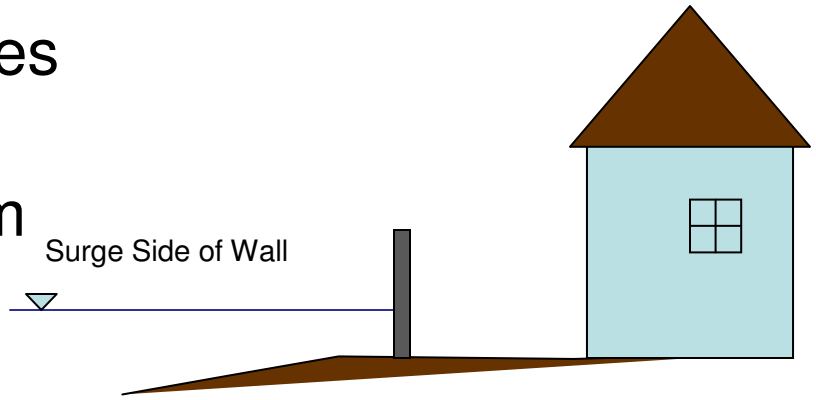
Brick cover over water proofing

Infrastructure Approaches

- Infrastructure
  - Structures and barriers
    - Tide gates with pump stations
    - Earth berms (and raised roads)
    - Floodwalls & bulkheads
  - Storm water system upgrades
    - Retention ponds
    - Increase drainage system capacity
  - Raising of structures and roads



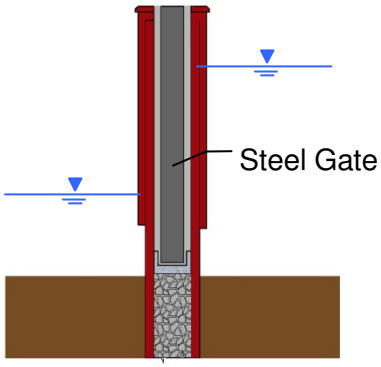
Earthen Berm



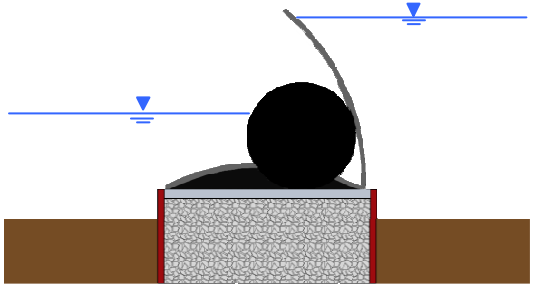
Flood Wall

Tide Gate Type Options

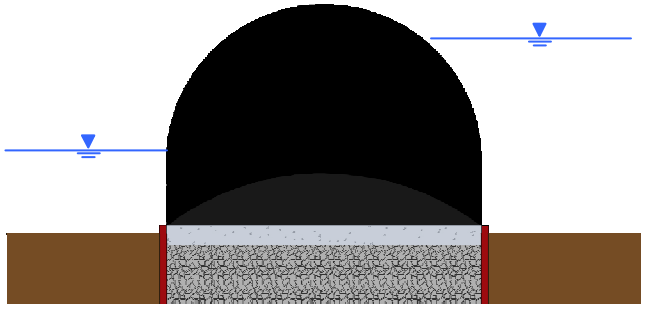
- Evaluated multiple types of tide gates, including:
  - Steel gates
  - Obermeyer gates (hybrid of above steel gate with bladder)
  - Inflatable dams
- Considerations Included:
  - Navigation requirements (affects length and depth)
  - Tidal flow
  - Initial capital and future O&M costs
  - Reliability



Steel Gate Option



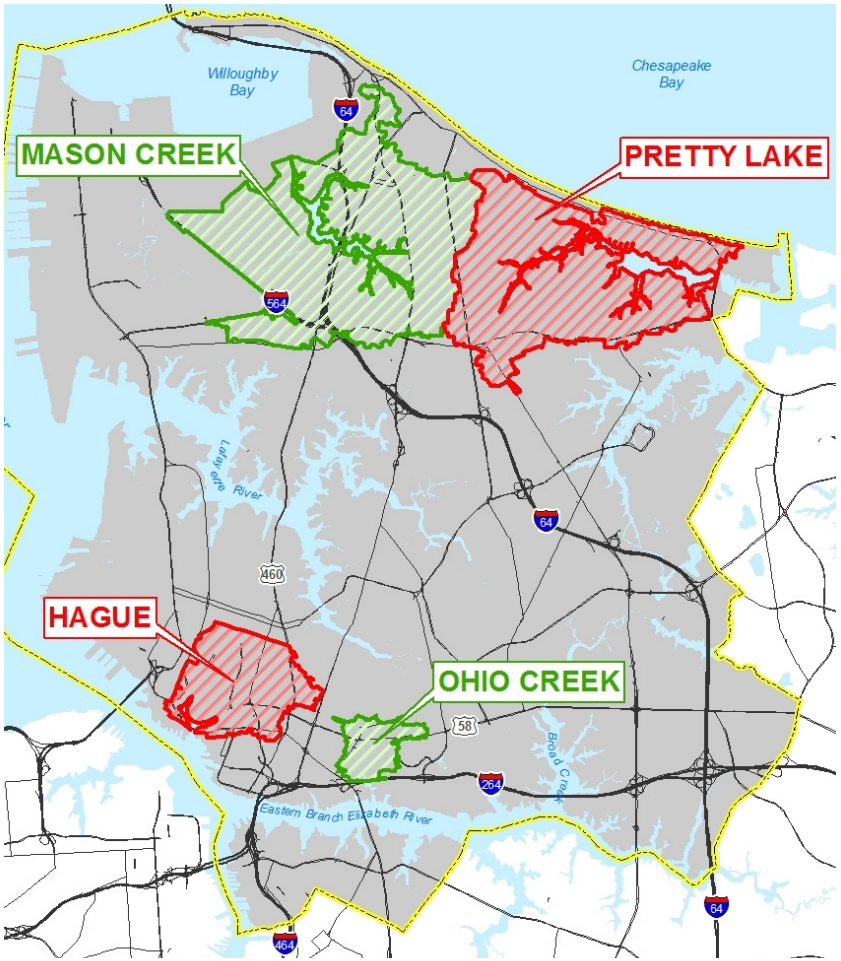
Obermeyer Gate Option



Inflatable Dam Option

Initial Focused Study Areas

- Choices based on:
  - Geographic setting
    - Areas with natural constriction points
  - Watersheds which lend themselves to specific, basin-wide mitigation options
  - Areas of recurring damage



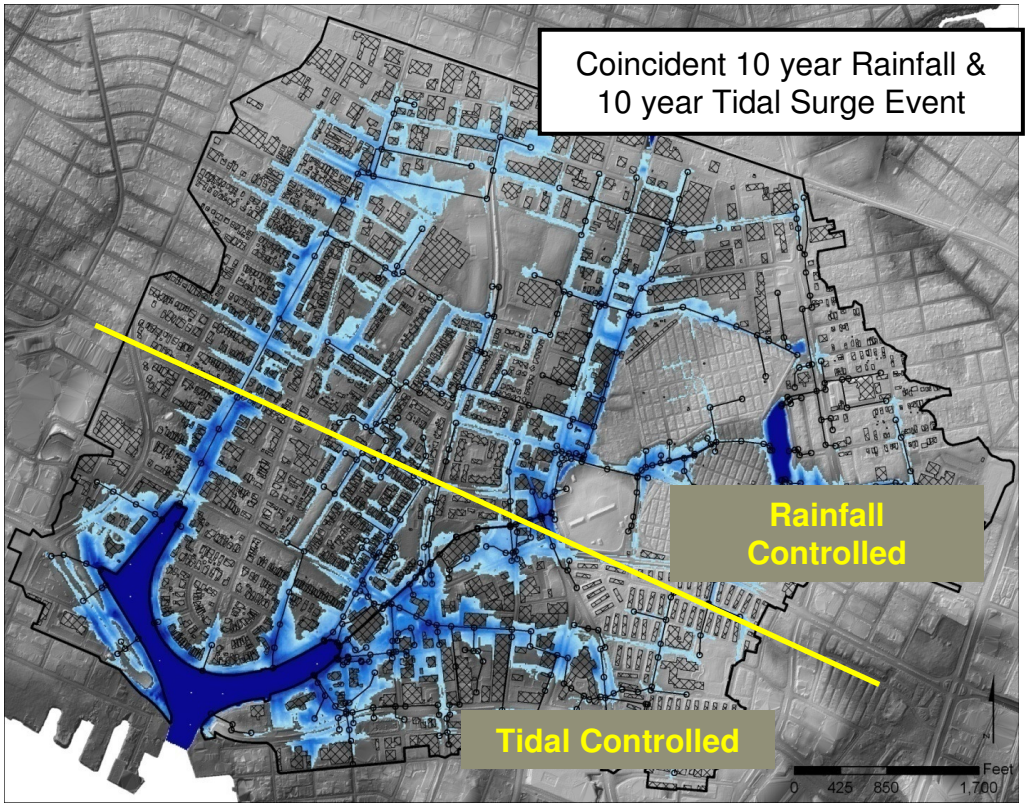
Watershed Characterization

Development Characteristics		The Hague	Pretty Lake	Mason Creek	Ohio Creek (Spartan Village)
Size	Acres	900	2,545	3,234	277
	% of City	3%	7%	9%	1%
Parcels		2,373	7,721	6,680	781
Assessed Value	$M	1,624	1,812	1,604	1,949
	% of City	7%	8%	7%	8%
Structures (Primary structures does not include detached out buildings/garages)	Total	1,512	7,737	6,293	584
	Residential	1,044	7,280	6,146	523
	% of City	1%	9%	7%	0.6%
	Non-residential	468	457	147	61
Existing Tide Surge Control		No	No	Yes	Yes

Evaluation Process

- Engineering (hydrologic and hydraulic) analyses
  - Moffatt & Nichol (PL, MC, H) and Timmons Group (OC)

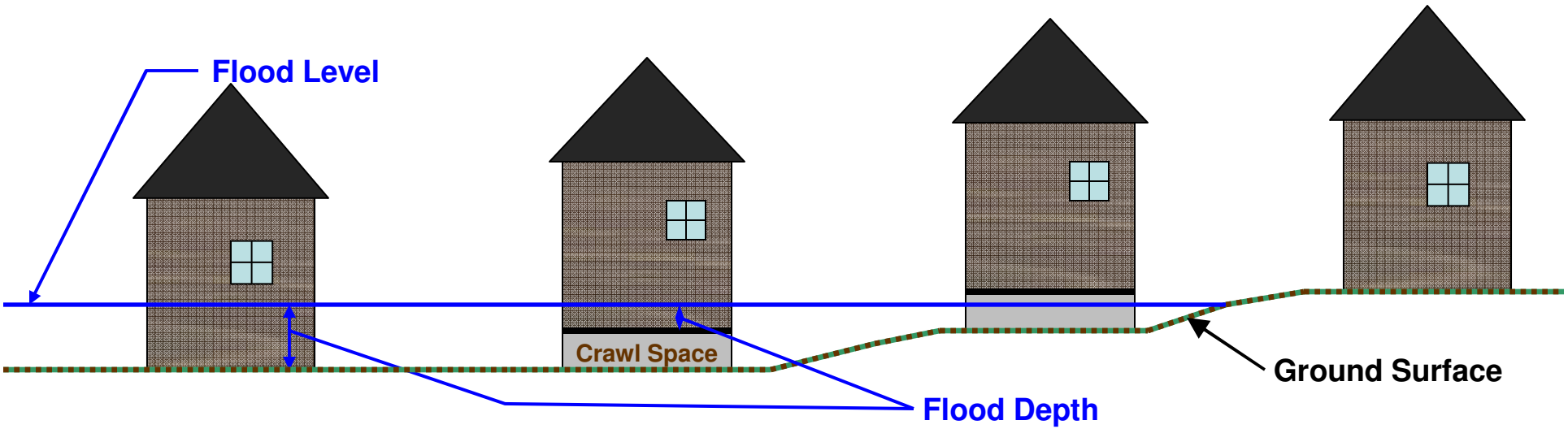
Storm water Infrastructure Model



Tidal surge:
1) Increases area of rainfall flooding
2) Increases depth of rainfall flooding and
3) Holds water upstream longer and increases duration of flooding

Evaluation Process

- GIS-based approach using FEMA and USACE procedures
- Modeling includes structures & contents utilizing the City parcel database and field verification was performed
- Not included in model are ancillary structures, vehicles, displacement, loss of use and city infrastructure

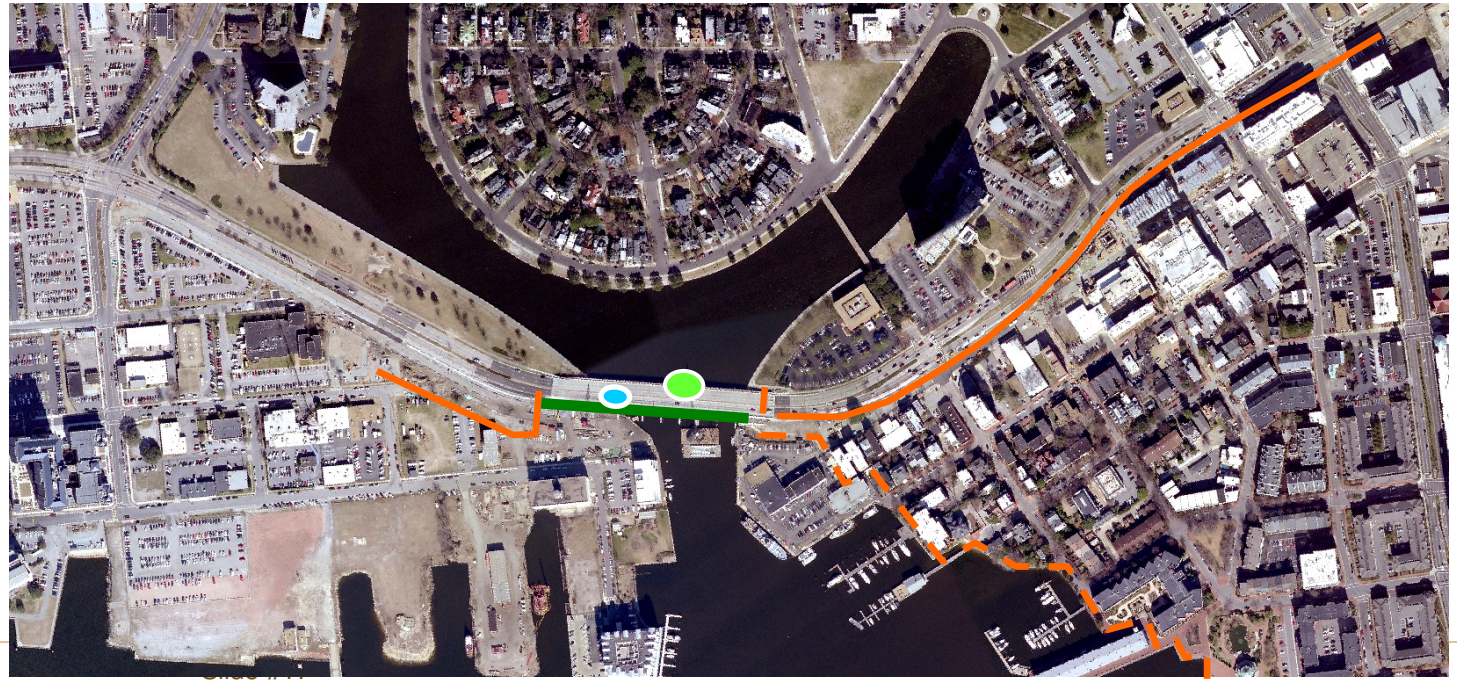


Evaluation Process

- Project cost estimates
  - Include ancillary structures (tie-in walls)
  - Pump stations
  - Long-term operation and maintenance
- Benefit cost analysis
  - Compares benefit of project to cost of project
- Recommend options based on
  - Benefit cost analysis
  - Initial cost and operation/maintenance cost
  - Reliability

The Hague: Project Elements

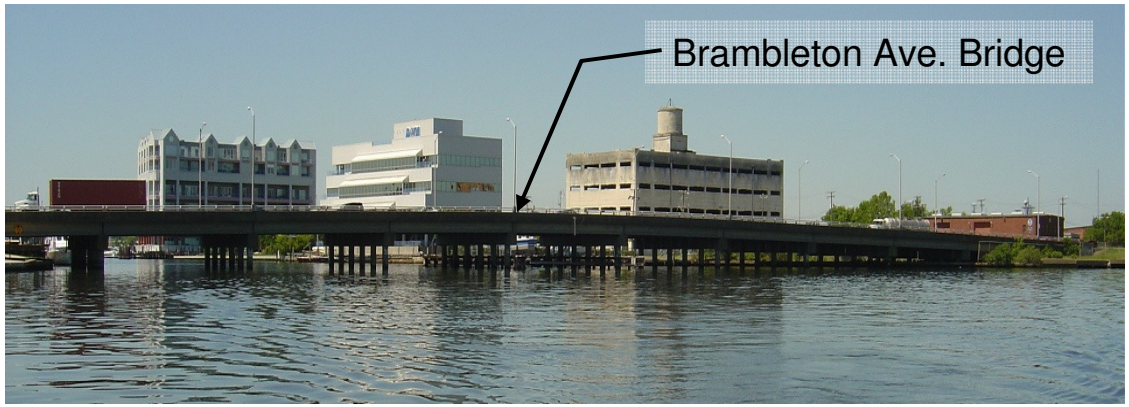
- Capital Project to protect against coastal flooding (tidal surge):
  - **Tidal Barrier (floodwall)** to protect against tidal surge
    - **Tide gate** – if navigation access required
  - **Pump station** to remove rainfall runoff when gate closed
  - **Closure walls or berms** across where land surface is low around basin/watershed perimeter

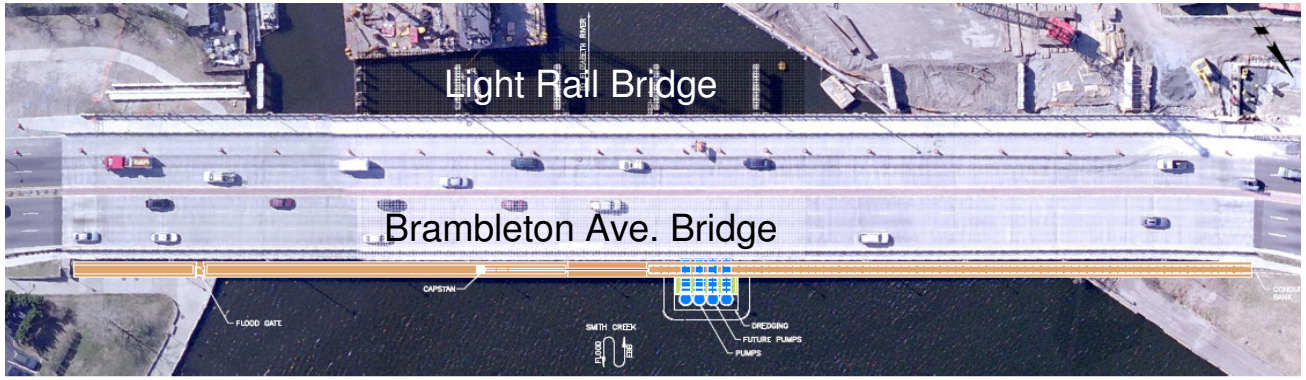


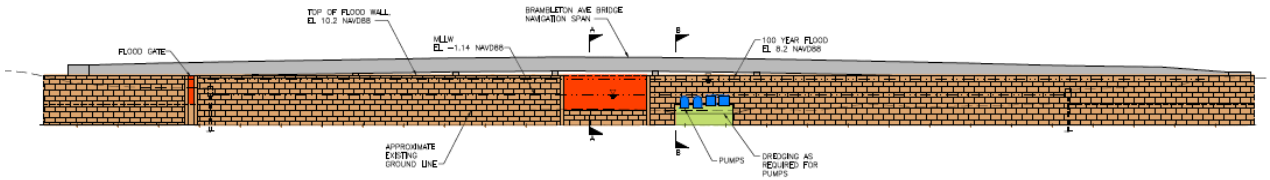
The Hague - Recommended Mitigation Approach

Project Elements

- Floodwall
- Tide Gate
- Pump Station
- Closure Walls







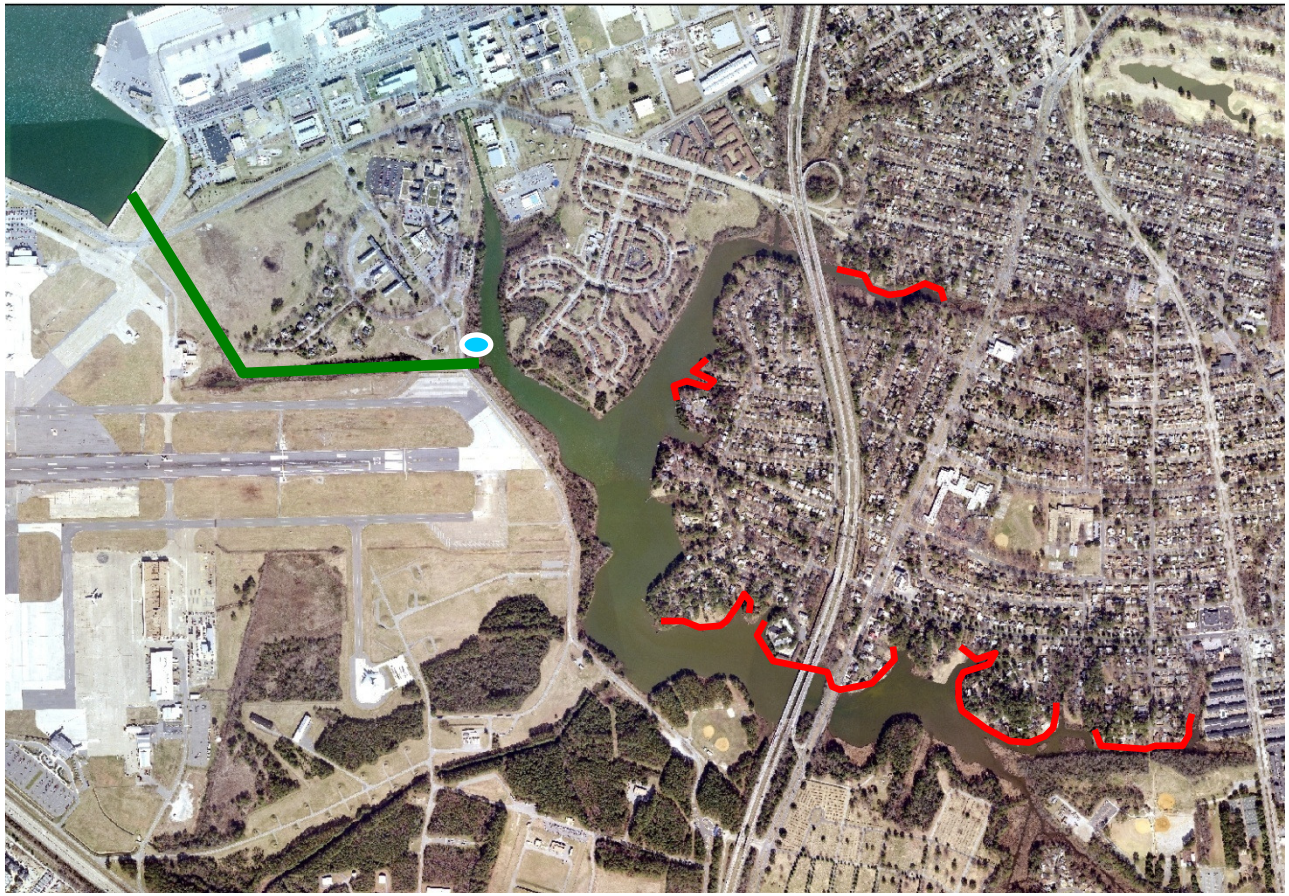
Mason Creek – Project Elements

CAPITAL PROJECT intended to protect against rainfall runoff (Area protected from Tidal Surge by Existing Tide Gate (operated by Navy) will require:

- Pump station to remove rainfall runoff when gate closed
- New Storm Culvert beneath Navy

OPTIONAL APPROACH

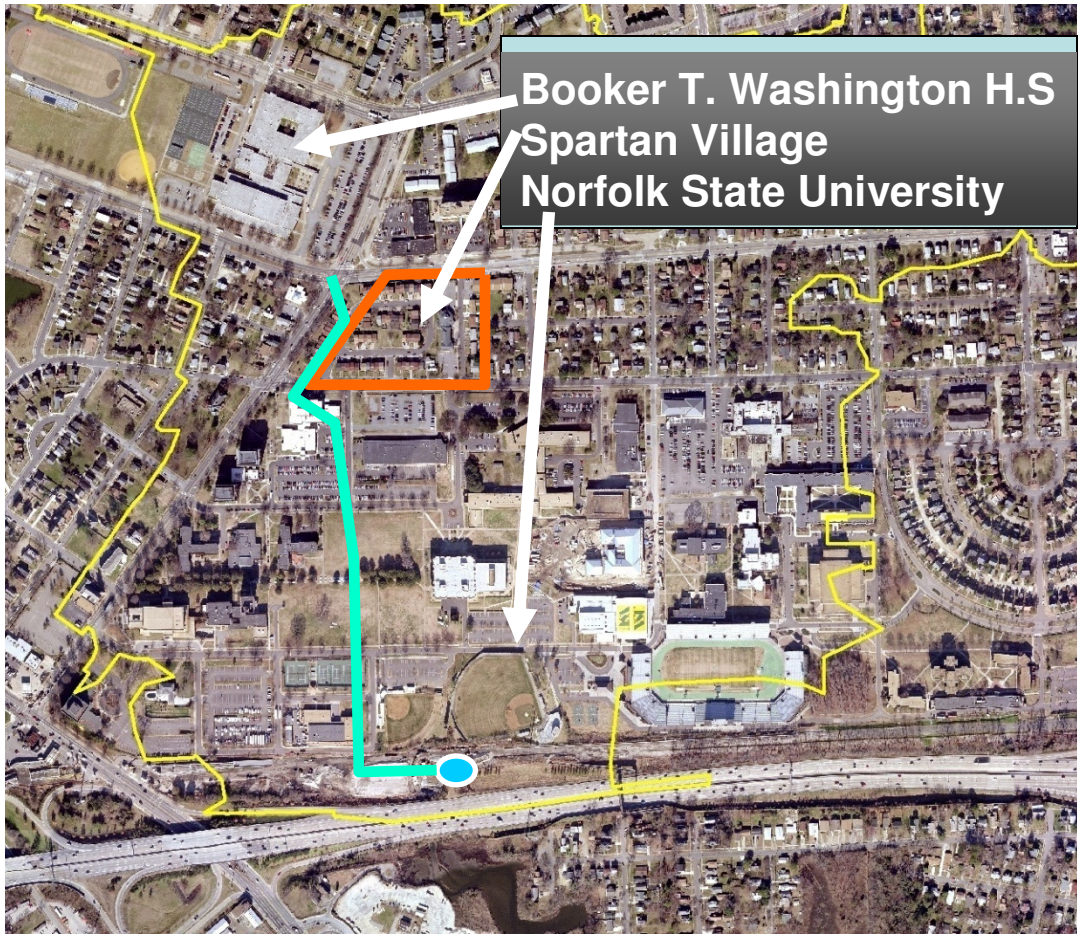
- Peripheral walls (or berms) where land surface is low around Creek
- Structure elevation
- Future building requirements



Ohio Creek: Project Elements

Capital Project Phased as Follows:

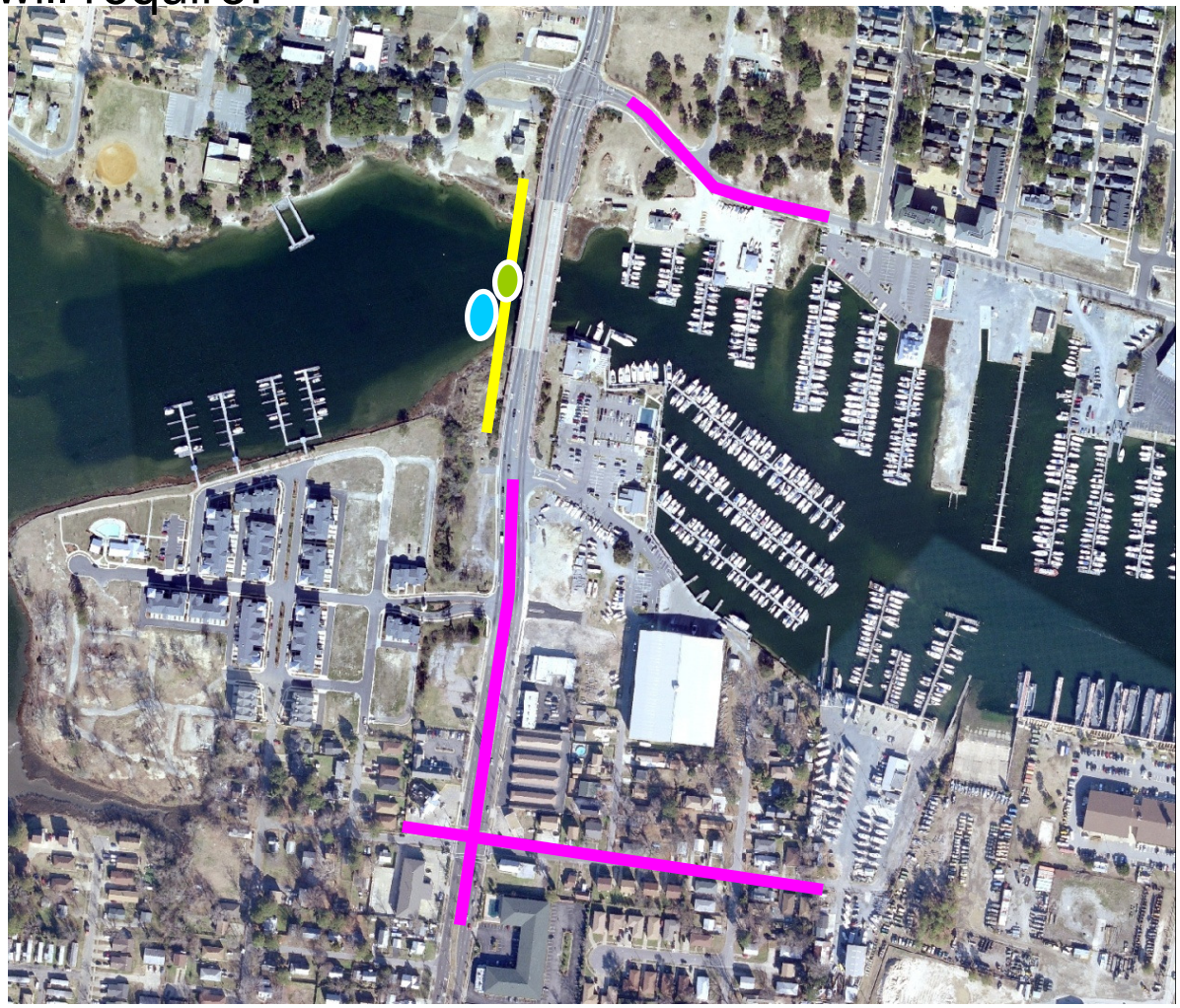
- **Phase 1** – Buyout of most vulnerable properties -50 year option
- **Phase 2** – Pump Station (reduces rainfall impact during tidal surge) - 100 year option
- **Phase 3** – Box Culvert (improves drainage system)



Pretty Lake – Project Elements

Capital Project intended to protect against both coastal flooding (tidal surge) and rainfall runoff will require:

- Tidal Barrier (floodwall) structure to protect against inundation from tidal surge
- With tide gate to preserve navigation access required
  - Tide gate needs foundation
- Pump station to remove rainfall runoff when gate closed
- Raise roads where land surface is low around basin/watershed perimeter



Pretty Lake – Recommended Project

Project Elements

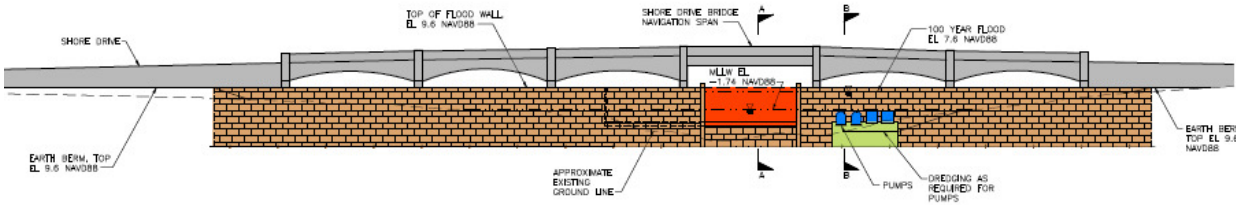
- Floodwall
- Tide Gate
- Pump Station
- Road Raise

Design Basis

- 100 year storm
- Note storm water system capacity will cause local flooding for rainfall in excess of 2 year return period

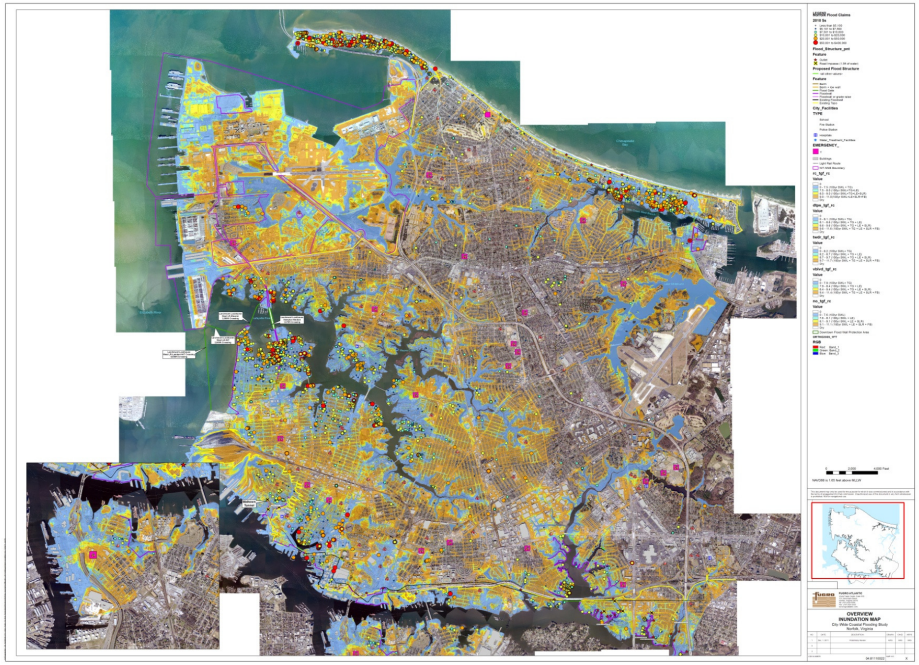
Capital Cost

- $50M to $100M (2011 Dollars)
- B / C ratio: 2.1

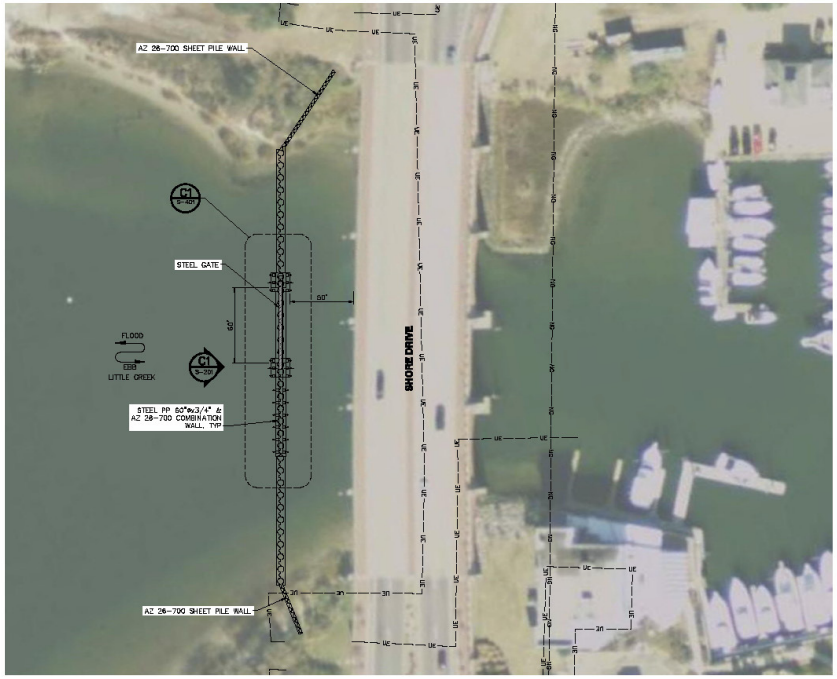


Current Activities

- Preliminary design of watershed areas
- Evaluating mitigation options for other watersheds
- City-wide coastal flood risk assessment



City-wide Risk Assessment



Preliminary Design

Other City Activities

- Developing a strategic plan for the entire City that will guide the application of resources city-wide to address storm water and flooding
- Met with Congressmen Bobby Scott and Scott Rigell and their staff to discuss the City's flooding issues and the federal government's role
- Conducted tour of coastal flood prone areas of the City for the U.S. Army Corps of Engineers, District, Division and Headquarters officials
- Work with the City's delegation to have the State Legislature begin studying and addressing this issue
- Attempting to reallocate existing funds to begin work on some immediate projects at the federal level

Continuing Actions

- Pursue technical and political solutions to this complex issue
- Continue to seek engagement of state and federal resources
- Increase citizen knowledge and understanding
- Mitigate damages and losses from flooding
- Seek out and listen to experts for creative mitigation options
- Adapt land use, zoning and building regulations

Thank You

for the Opportunity to contribute to the City of Norfolk's Future